Solar Ultraviolet Radiation and Health

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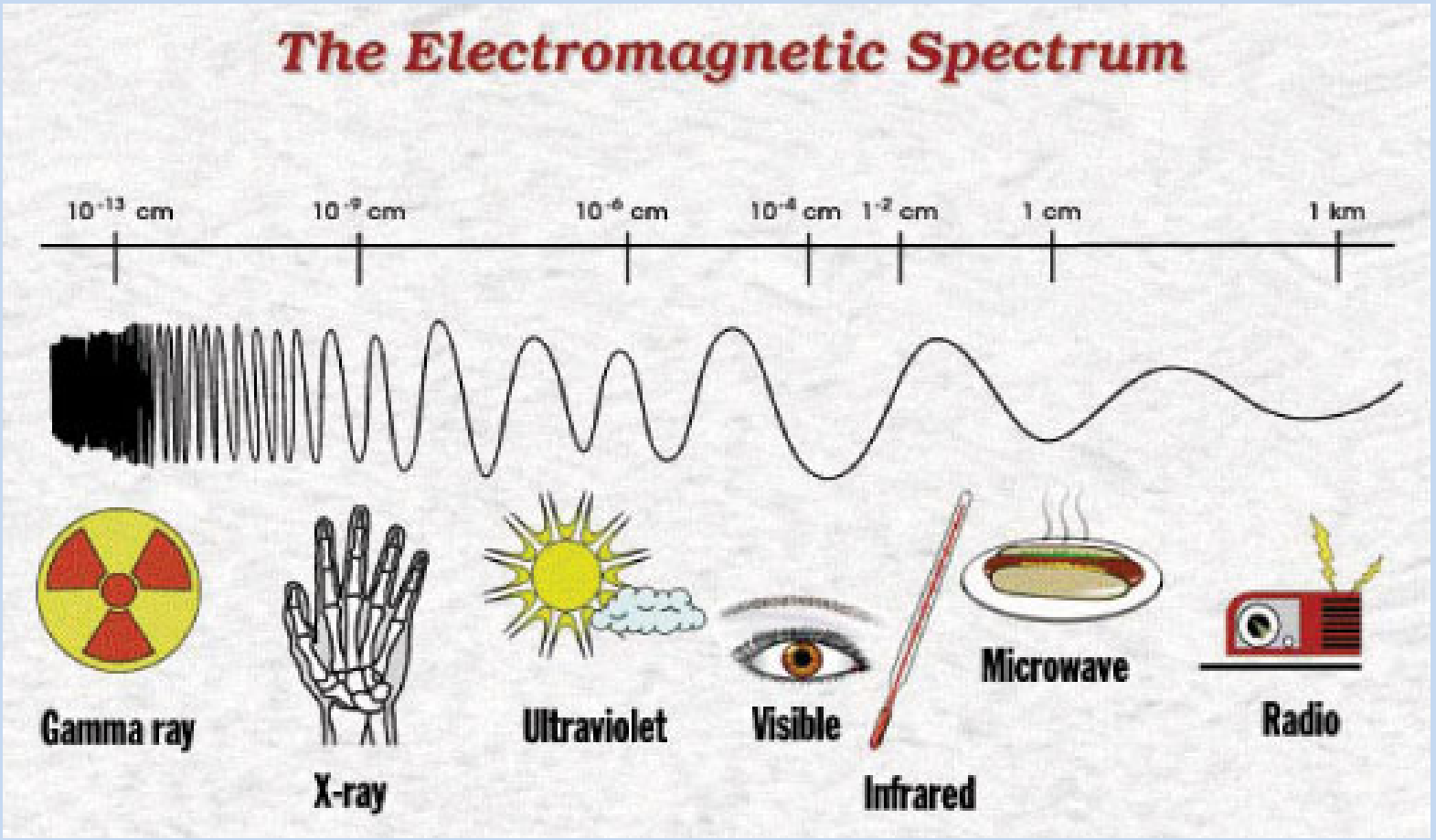
Radiation Epidemiology & Dosimetry Course

National Cancer Institute www.dceg.cancer.gov/RadEpiCourse

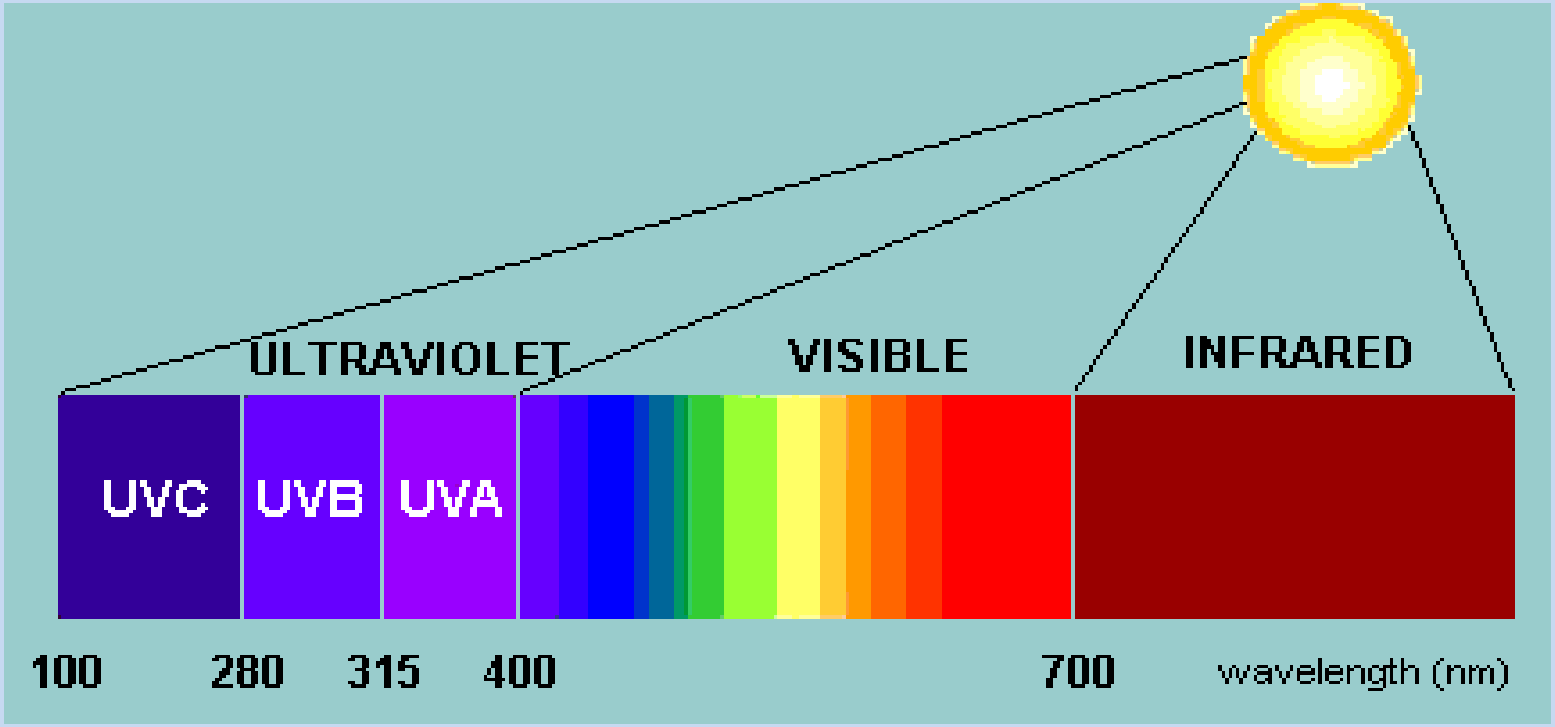
Presentation overview

- Background on UV radiation (UVR)
- UVR exposure assessment
- Health risks
- Health benefits
- Summary

Background on UV Radiation


The Electromagnetic Spectrum
10^-13 cm
10^-9 cm
10^-6 cm
10^-4 cm
1^-2 cm
1 cm
1 km
Gamma ray
X-ray
Ultraviolet
Visible
Infrared
Microwave
Radio

Solar radiation spectrum



95% of UVA: 315-400 nm

5% of UVB: 280-315 nm

Skin erythema (reddening) response to various UVR wavelengths

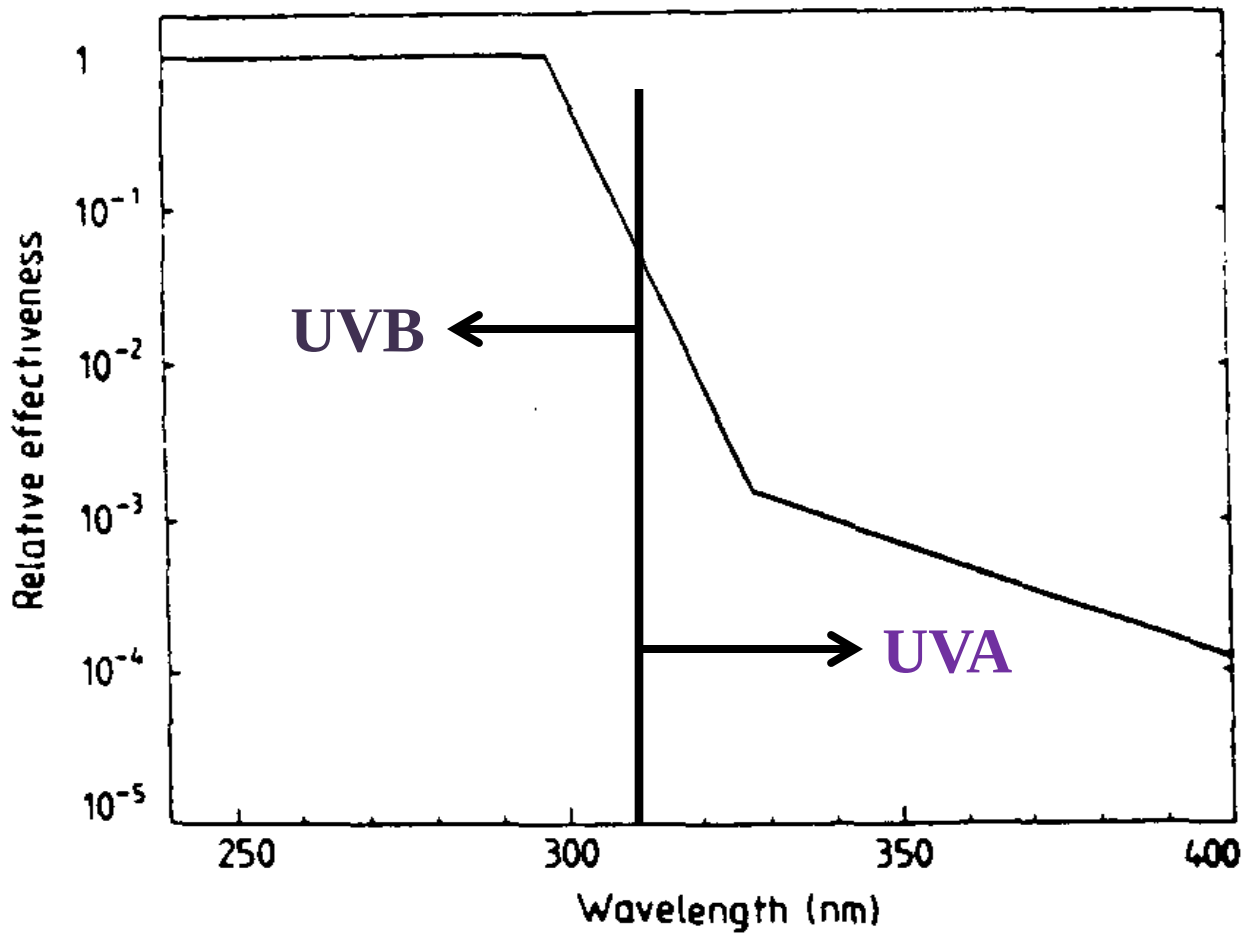


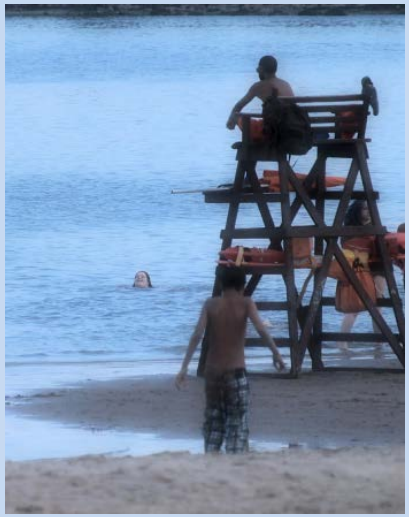
Figure 7. The CIE reference erythema action spectrum (McKinlay and Diffey 1987).

UV Radiation Exposure Assessment

Surrogates for UVR

<u>Individual measures</u>

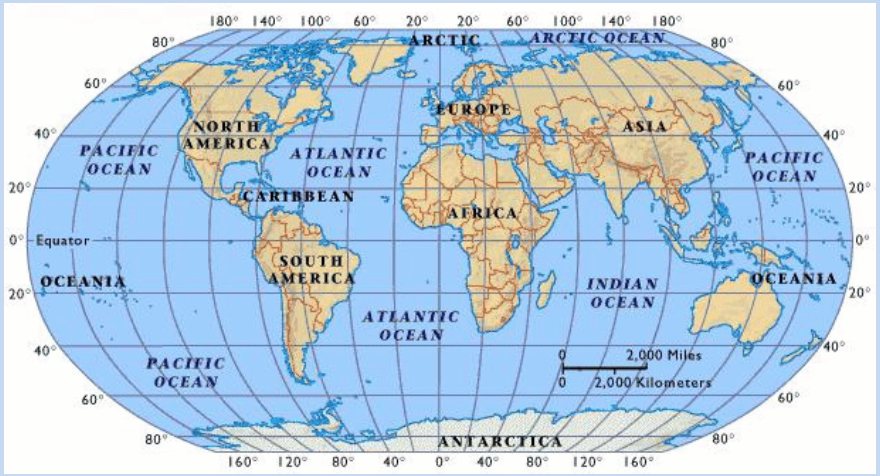
- Self-reported time outdoors
- Outdoor/indoor occupation
- Tanning bed use
- Lack of sunscreen use/protective clothing
- Sunburns



Surrogates for UVR

Environmental measures

- Proximity to the Equator
- Ambient UVR
  - Ground-based
  - Satellite-based



Total Ozone Mapping Spectrometer

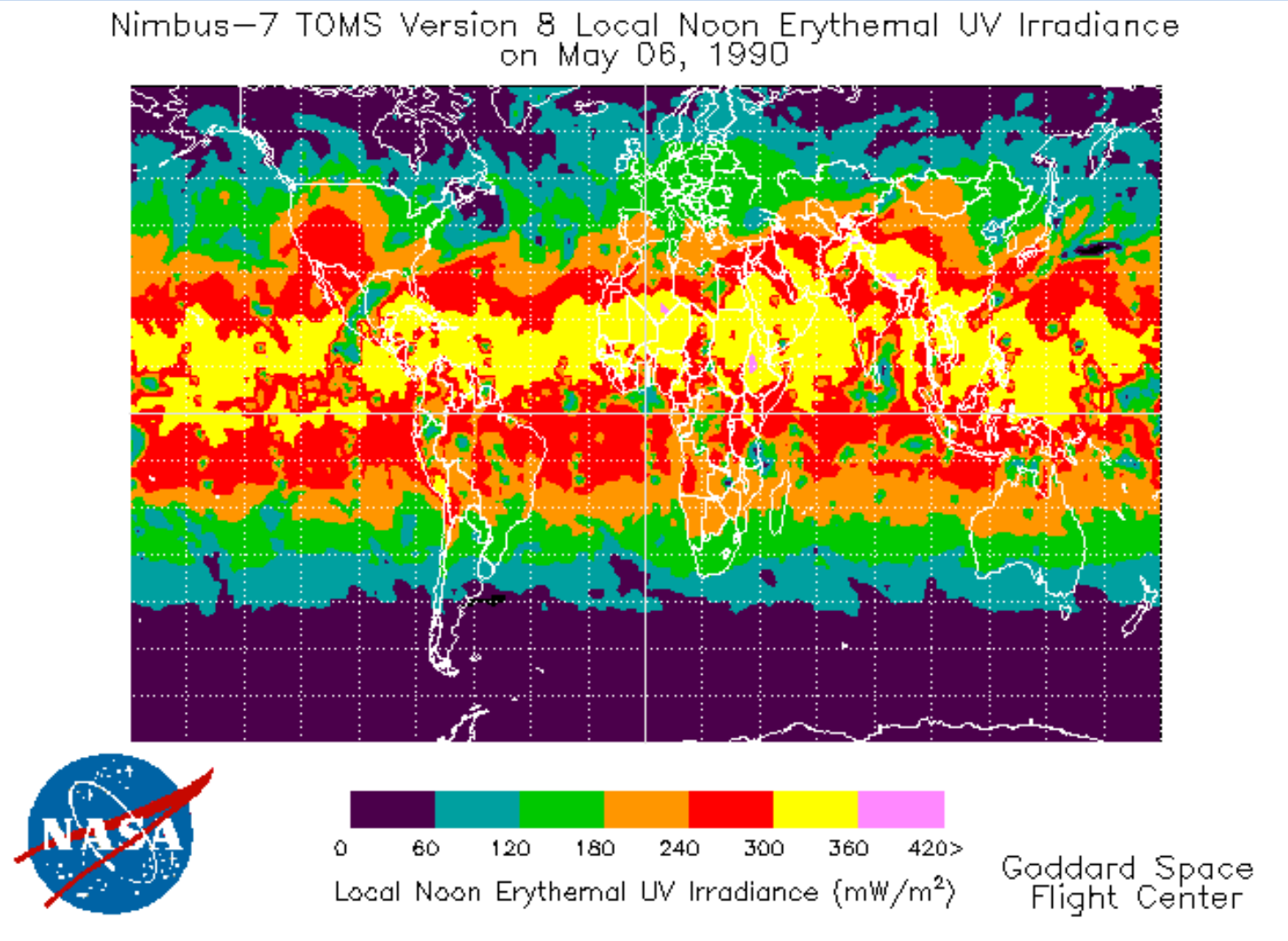
Ozone Processing Team - NASA/GSFC Code 613.3

Nimbus-7 Satellite

- Satellite circled Earth once a day near noontime
- Validated by ground-based measurements
- Publically available at:

http://toms.gsfc.nasa.gov

Satellite-based ambient erythemal UVR



http://toms.gsfc.nasa.gov/n7toms/nim7toms_v8.html

Erythemal exposure model

The Erythemal Exposure is defined by the integral

$$\text{Exp.} = \frac{1}{d_{\text{es}}^2} \int_{280\text{nm}}^{400\text{nm}} d\lambda\, S(\lambda) W(\lambda) \int_{t_{\text{sr}}}^{t_{\text{ss}}} dt\, C(\lambda, \vartheta, \tau_{\text{cl}}) F(\lambda, \vartheta, \Omega)$$

where

d_{es} = Earth-Sun distance, in A.U.

S = Solar irradiance incident on the top of the atmosphere at 1 A.U.

W = Biological action spectrum for erythemal damage (see below).

t_{sr}, t_{ss} = Time of sunrise, time of sunset.

C = Cloud attenuation factor.

τ_{cl} = Cloud optical thickness.

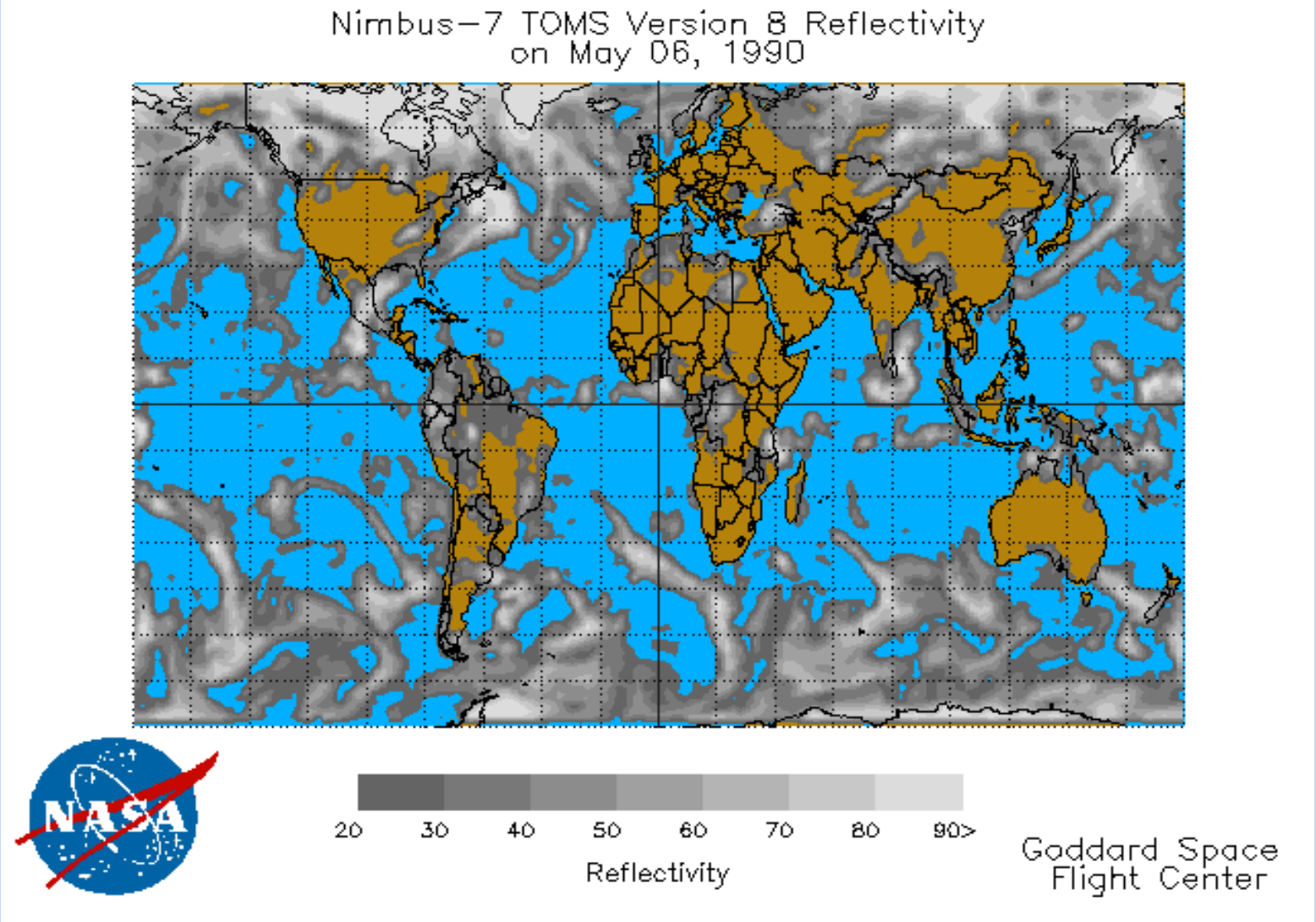
ϑ = Solar zenith angle (function of time, t).

F = Spectral irradiance at the surface under clear skies, normalized to unit solar spectral irradiance at the top of the atmosphere.

Ω = Total column ozone.

http://macuv.gsfc.nasa.gov/doc/erynotes.pdf

Reflectivity



http://toms.gsfc.nasa.gov/n7toms/nim7toms_v8.html

UV Radiation

The bad news

Risks of UVR exposure to the eye

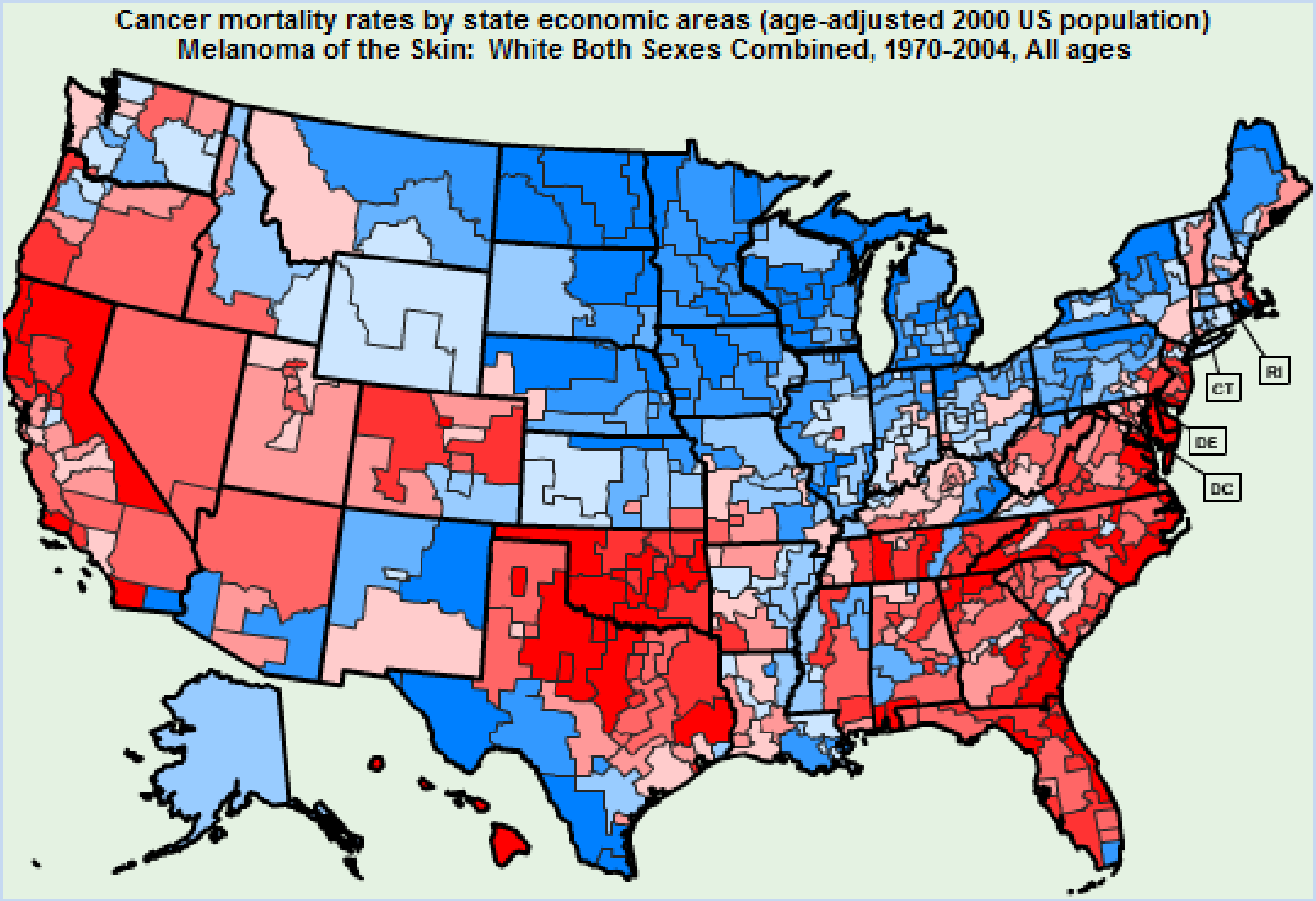
- Cataracts
  - Causes blindness in 16 million people annually
  - WHO estimates 20% of cataracts caused by UVR
- Melanoma
  - Risk factors include white race, light eye color, fair skin
  - Evidence for UVR inconsistent

Cataract

Uveal melanoma

Muen and Damato. Eye, 2007.

Melanoma mortality



Risks of UVR exposure to the skin

- Melanoma
  - 80,000 annual cases in the U.S.
  - 10,000 deaths
- Basal cell carcinoma
  - 2.8 million diagnosed annually in the U.S.
  - Most common cancer in U.S.
- Squamous cell carcinoma
  - 700,000 diagnosed each year in the U.S.
  - 3,900 to 8,800 deaths

Cumulative UVR and skin cancer

Research Article

Cancer Epidemiology, Biomarkers & Prevention

Long-term Ultraviolet Flux, Other Potential Risk Factors, and Skin Cancer Risk: A Cohort Study

Shaowei Wu[1,2], Jiali Han[1,2,3,5], Francine Laden[2,3,4], and Abrar A. Qureshi[1,2,6]

Basal cell carcinoma

UVR	HR	95% CI	P-trend
Q1	Ref		
Q2	1.34	1.09–1.66	
Q3	1.63	1.27–2.08	
Q4	1.91	1.46–2.48	
Q5	2.35	1.79–3.07	<0.0001

Squamous cell carcinoma

UVR	HR	95% CI	P-trend
Q1	Ref		
Q2	1.37	0.69–2.74	
Q3	1.71	0.79–3.73	
Q4	2.16	0.96–4.85	
Q5	2.53	1.11–5.77	0.009

Wu. CEBP, 2014.

Cumulative UVR and skin cancer

Melanoma

UVR	HR	95% CI	P-trend
Q1	Ref		
Q2	0.74	0.44–1.25	
Q3	0.6	0.33–1.09	
Q4	0.72	0.37–1.38	
Q5	0.68	0.34–1.34	0.38

Number of blistering sunburns between ages 15–20	HR	95% CI
None	Ref	
1-4	1.32	1.11-1.57
≥5	1.80	1.42–2.28

Wu. CEBP, 2014.

Factors in UVR-related skin cancer risks

Well-known

- Skin/hair/eye pigmentation
- Family history of skin cancer

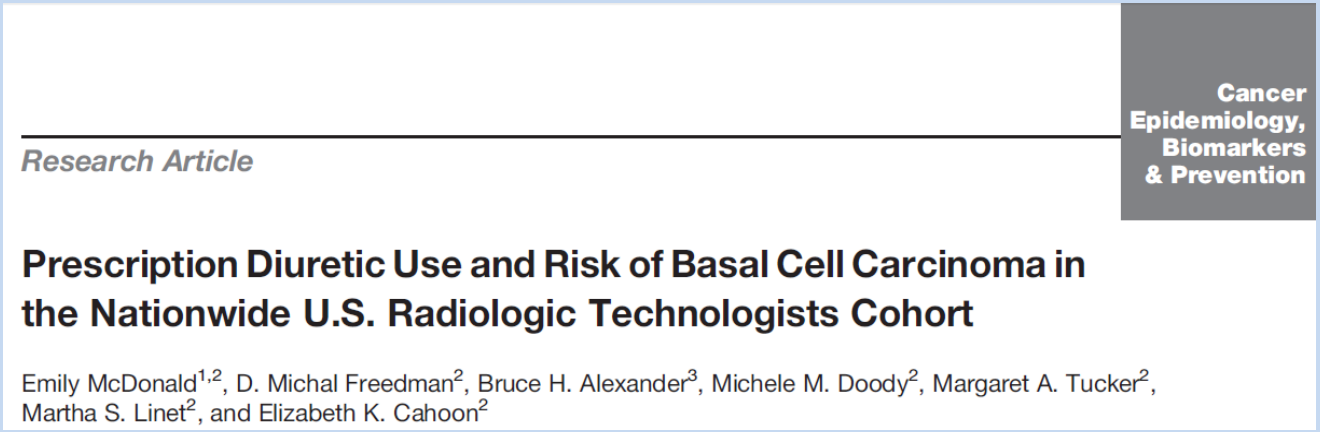
New research

- Photosensitizing medications
- Immune deficiency
- UV radiation wavelength

Drug-induced photosensitivity

Class	Medication
Antibiotics	Tetracyclines
	Fluoroquinolones
	Sulfonamides
Nonsteroidal anti-inflammatory drugs	Ibuprofen
	Ketoprofen
	Naproxen
	Celecoxib
Diuretics	Furosemide
	Hydro-chlorothiazide
Retinoids	Isotretinoin
	Acitretin
Sunscreens	Para-aminobenzoic acid
	Cinnamates
	Benzophenones
	Salicylates

Diuretics and basal cell carcinoma



Research Article

Cancer Epidemiology, Biomarkers & Prevention

Prescription Diuretic Use and Risk of Basal Cell Carcinoma in the Nationwide U.S. Radiologic Technologists Cohort

Emily McDonald[1,2], D. Michal Freedman[2], Bruce H. Alexander[3], Michele M. Doody[2], Margaret A. Tucker[2], Martha S. Linet[2], and Elizabeth K. Cahoon[2]

Total population	HR	95% CI		P for trend
Diuretic, ever				
No	Ref			
Yes	1.22	1.07	1.38	
Diuretic, length of use				
Never	Ref			
<6 months	0.96	0.75	1.23	
6 months- 2 years	1.22	0.96	1.53	
>2 years	1.38	1.16	1.64	<0.001

Overweight	HR	95% CI	
Diuretic, ever			
No	Ref		
Yes	1.43	1.16	1.76

Normal weight	HR	95% CI	
Diuretic, ever			
No	Ref		
Yes	0.99	0.81	1.21

McDonald. CEBP, 2014

Limitations in examining drug-induced photocarcinogenesis

- Surveillance bias
- Confounding by indication
- Clarifying biological mechanisms
- Cancer registries often do not ascertain or confirm non-melanoma skin cancers
- Large databases do not provide measures of UV radiation exposure

Immune suppression and skin cancer risks

Skin cancer risks in persons HIV(+) vs. HIV(-)

Skin cancer	SIR
Squamous cell carcinoma	2.6
Basal cell carcinoma	2.1

Silverberg. JNCI, 2013.

Skin cancer in organ transplant recipients

Skin cancer	SIR
Squamous cell carcinoma	65
Basal cell carcinoma	10
Melanoma	3

Other risk factors

UVR exposure

Intensity of immunosuppression

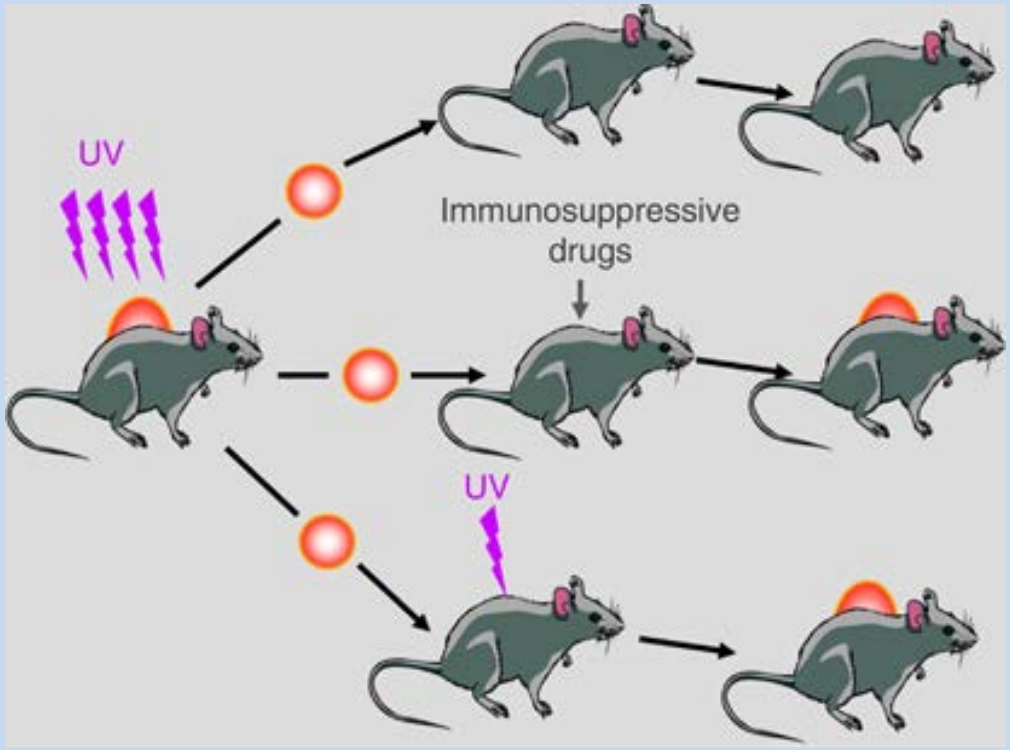
Photosensitizing medications (antifungals)

Type of organ transplant

Zwald. J Am Ac Derm, 2011.

UV radiation prevents rejection of transplanted skin tumors

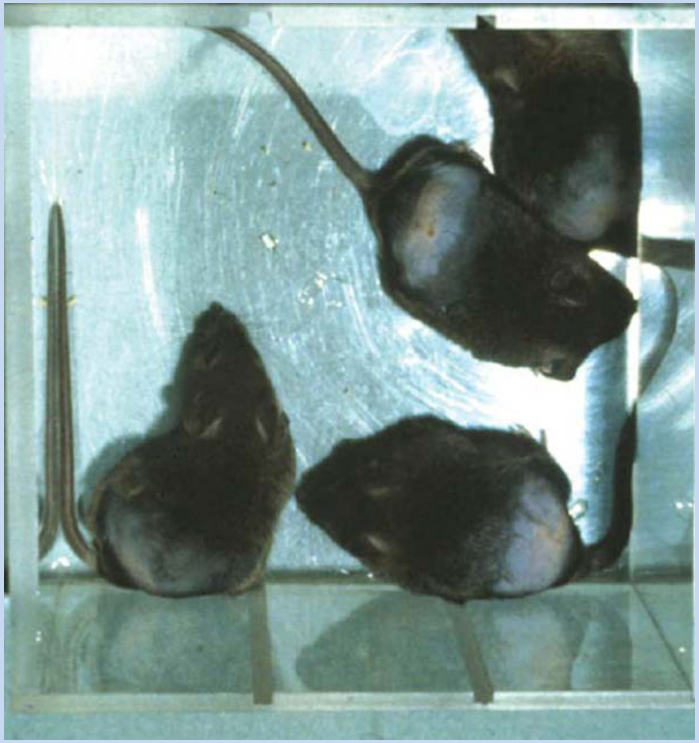
Seminal discovery by Margret Kripke (JNCI, 1974)



Schwarz. J Inv Derm, 2010.

UV radiation-induced immune suppression and vaccination effectiveness

Control

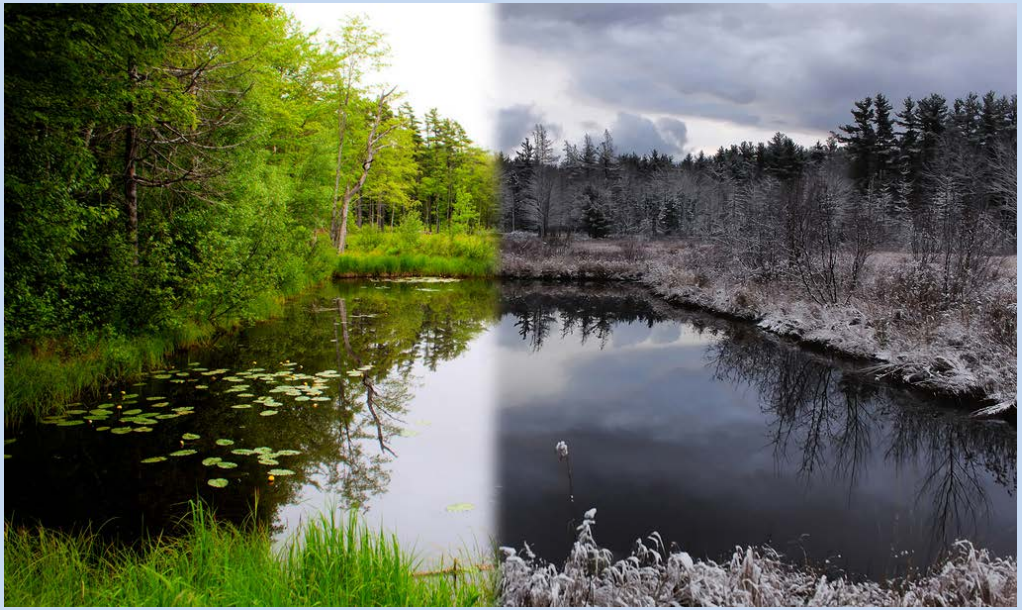


UV irradiated

Norval and Woods. Photochem. Photobiol. Sci., 2011.

Does vaccine effectiveness depend on UVR?

- Polio
- Influenza
- Hepatitis B
- Rubella
- TB
- Measles



UVA *versus* UVB

Wavelength dependent characteristics of solar UV radiation

UVA

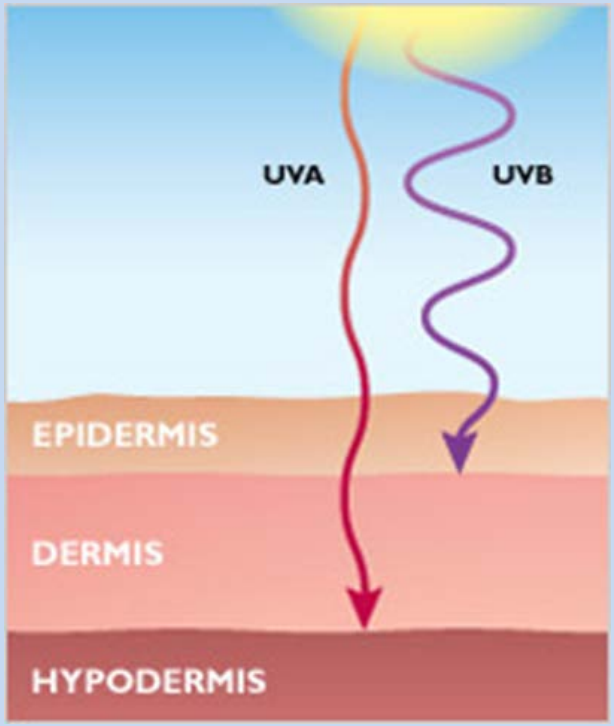
- 95% of UVR
- Not absorbed by ozone layer
- Deeper skin penetration
- Doesn’t cause sunburn
- Indirect DNA damage through oxidative stress
- Skin does not adapt
- Breaks down vitamin D bound to VDR

UVB

- 5% of UVR
- Partially absorbed by ozone layer
- Penetrates top layer of skin
- Causes sunburn
- Direct DNA damage
- Skin adaptation (thickening of outermost layer of the epidermis and production of melanin)
- Vitamin D production

Importance of delineating roles of UVA and UVB

- Historically, sunscreens protected from sunburn (UVB)
- Tanning beds designed to emit mostly UVA
- Windows (including auto glass) transmit only UVA



Incomplete protection?

The Washington Post

To Your Health

Why the newest sunscreens still haven't hit the U.S. market

By Brady Dennis May 11 Follow @brady_dennis

The New York Times

THE CONSUMER

The New Rules for Sunscreen

By RONI CARYN RABIN MAY 27, 2013 3:30 PM 194 Comments

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There is no question most skin cancers are related to sun exposure, yet even with sunscreen sales approaching $1 billion a year, skin cancer rates continue to climb. Melanoma diagnoses have risen nearly 2 percent a year since 2000 and are increasing even more among young white women.

Some experts blame inappropriate use of sunscreen, saying that people do not apply enough lotion (a golfball-size dollop) or do not reapply it every two hours as instructed. But there's

UV Radiation

The good news

Benefits of UV Radiation

- Vitamin D production promotes healthy bones and muscles
- UVR treatment
- Reduced risk of autoimmune conditions
- Reduced risk of some cancers

UV radiation treatment

- Rickets
  - softening of bones in children
- Lupus vulgaris
  - tuberculosis of the skin
- Vitiligo
  - autoimmune disease causing patchy loss of skin pigmentation due to destruction of melanocytes
- Psoriasis
  - autoimmune disease of skin causing sores and scaling of the skin
  - 2-3% of the population

UV radiation and reduced risk of some autoimmune diseases

- Type 1 diabetes
- Rheumatoid arthritis
- Multiple sclerosis

UVR and reduced cancer risks

IJC
International Journal of Cancer

Prospective study of ultraviolet radiation exposure and risk of cancer in the United States

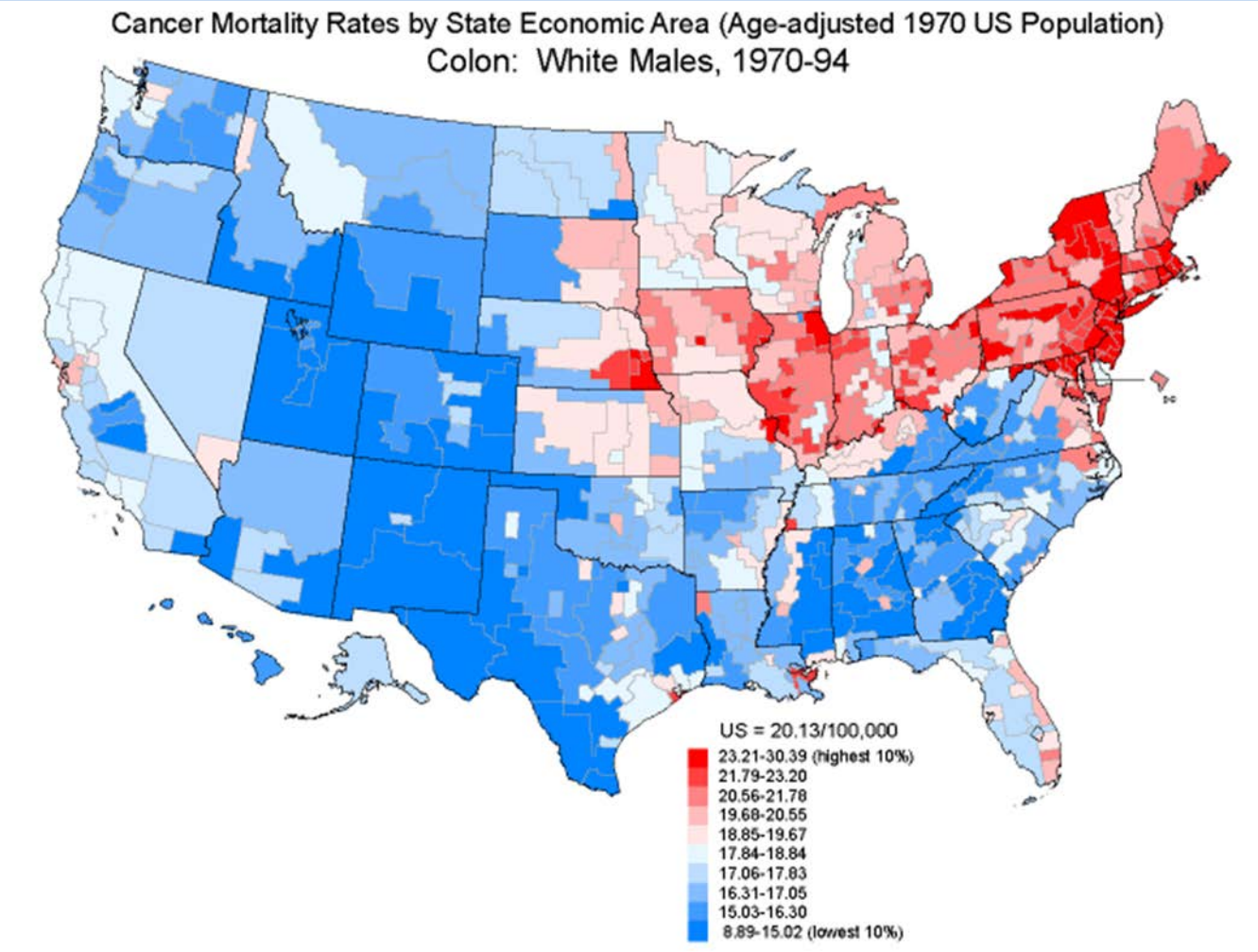
Shih-Wen Lin[1,2], David C. Wheeler[3], Yikyung Park[2], Elizabeth K. Cahoon[2], Albert R. Hollenbeck[4], D. Michal Freedman[2] and Christian C. Abnet[2]

Key findings

Reduced risks for colon, female breast, NHL, HL, prostate, lung, kidney, and bladder cancer

Lin. IJC, 2012.

Colon Cancer Mortality



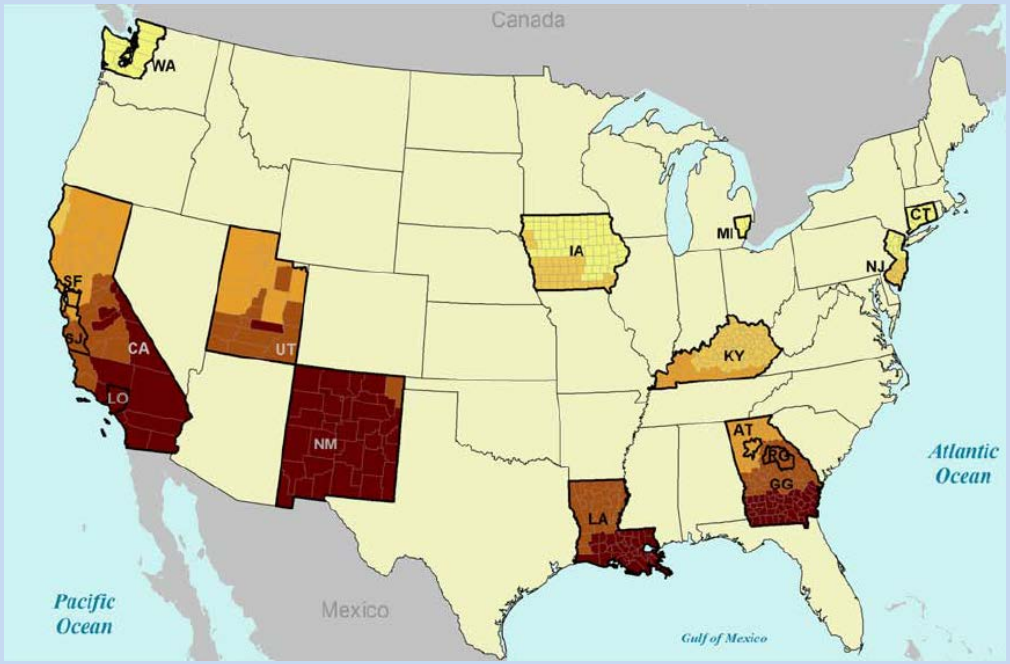
Ambient UV radiation and NHL in the U.S.

Population: U.S. population-based SEER cancer registries, 2001-2010

Exposure:

Satellite-based ambient UVR exposure (quintiles)

Outcome: NHL subtypes (N=187,78 cases)



Cahoon. IJC, 2014.

Ambient UV radiation and NHL in the U.S.

NHL subtype	RR for UVR Q5 vs Q1 (95% CI)	P-trend
CLL/SLL	0.87 (0.77,0.97)	0.114
Follicular lymphoma	0.76 (0.68,0.86)	<0.001
Diffuse large B-cell lymphoma	0.84 (0.76,0.94)	<0.001

Cahoon. IJC, 2014.

Summary

- Risks include skin cancers, eye disease, and systemic immune suppression
- Benefits include treatment, vitamin D production, potentially reduced risks of some autoimmune diseases and cancers
- Future research aimed at refining our understanding and quantifying risks and benefits to guide public health policies

Thank you

Questions and Answers

U.S. Department of Health and Human Services
National Institutes of Health | National Cancer Institute
www.dceg.cancer.gov/RadEpiCourse
1-800-4-CANCER
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